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A Comprehensive Review on Renewable Energy Development, Challenges, and Policies of Leading Indian States With an International Perspective

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ABSTRACT Clean and environment-friendly energy harvesting are of prime interest today as it is one of the key enablers in achieving the Sustainable Development Goals (SDGs) as well as accelerates social progress and enhances living standards. India, the second-most populous nation with a population of 1.353 billion, is one of the largest consumers of fossil fuels in the world which is responsible for global warming. An ever-increasing population is projected until 2050, and consequently, the energy demand in the upcoming decades will be co-accelerated by the rapid industrial growth. The Ministry of New and Renewable Energy (MNRE) with the support of National Institution for Transforming India (NITI) Aayog is working to achieve the Indian Government's target of attaining 175 GW through renewable energy resources. Many Indian states are currently increasing their renewable energy capacity in an objective to meet future energy demand. The review paper discusses in-depth about the three Indian states, namely Karnataka, Gujarat, Tamil Nadu, which pioneers the renewable energy production in India. The global energy scenario was discussed in detail with Indian contrast. Further, the barriers to the development of renewable energy generation and policies of the Indian government are discussed in detail to promote renewable energy generation throughout India as well as globally since the challenges are similar for other nations. This study analyzed various prospects of the country in renewable energy which has been done in a purpose to help the scholars, researchers, and policymakers of the nation, as it gives an insight into the present renewable energy scenario of the country.

INDEX TERMS Renewable energy potential, global energy scenario, Energy policy in India, renewable energy barriers, prospects of renewables in India, renewable energy in India.

I. INTRODUCTION

In the present-day scenario, global warming harms the environment and the human race. The power systems energy production sector contributes nearly 75% of total CO_2 emissions in the world [1], which contributed to Greenhouse Gas (GHG) emissions as well as global warming. Thus, the United Nations is urging every nation in the world to comply with Sustainable Development Goals (SDGs) [2]. To slow down the effects of climatic changes, they are proposing to adopt renewable sources for meeting energy demands and reduce the per capita consumption [3]. Various countries have complied themselves following SDGs, by framing a structure of adoption of renewables, a road map to achieve its target and individual policies regarding renewable energy (RE) production. In India, National Institution for Transforming

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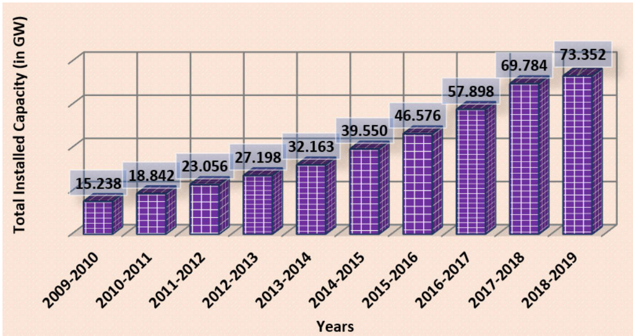

FIGURE 1. Growth of renewable energy over the past decade in India [9], [10].

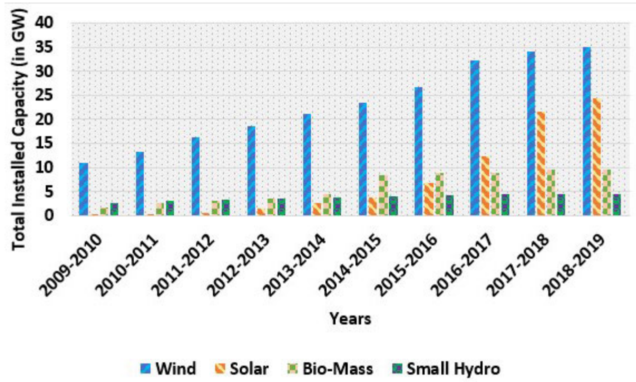

FIGURE 2. RE installed capacity (in GW) of various sources in recent years [9], [10].

India (NITI) Aayog, a non-statutory and advisory body, has taken the responsibility on the development of a comprehensive index to provide an integrated and combined view of the various socio-economic and substantial status of the country. It has also measured the progress of India and its state towards the accomplishment of the SDGs [4].

The energy demand in India is drastically increasing, and by 2030 India's total energy demand will be more than double while electricity demand will almost triple than today [5]. Moreover, current conventional sources are responsible for climates as well as unlimited in capacity. Hence, an alternative form of the generation which is cleaner and unlimited will be indispensable. RE installed capacity accounts for 22.5% [6] of India's total installed capacity for power production as of July 2019 [7]. India, the nation with abundant natural resources, has the immense potential for generating electricity through RE resources. The current day technologies have enabled for utilizing these renewable resources in a more efficient way of generating electricity [8]. Fortunately, India is blessed with abundant natural resources for commercial production of electricity through renewables. The various renewable resources which are commercially available for generating electricity in India are wind, solar, small-hydel, biomass, tidal, geothermal energy. The reason for the discussion of renewable energy status and potential in India is its significant potential in the nation. India has witnessed a tremendous escalation in renewable energy generation in the past ten years. The rise in the total installed capacity of RE in the country is depicted in Figure 1 [9], [10].

The Government of India has established the Ministry of New and Renewable Energy (MNRE) for developing and deploying alternative sources of energy generation and supplementing energy requirements of the country [11]. Since its formation, it has implemented various programs to increase electricity generation from RE resources. Additionally, the generation of RE resources needs less maintenance cost compared to non-renewable resources. India's RE potential is about 900 GW from various sources, namely, Wind- 12 %, Solar- 83 % which includes the wastelands, Bioenergy- 3 %, Small Hydro- 2.2 % [12]. India has committed to contribute to a healthier planet, and as per Paris Accord on climate change, it has pledged that by 2030, 40% of total power production will be from RE resources [13]. If this ambitious target is achieved, India will become one of the largest RE producers in the world. The RE installed capacity by type of RE sources is given in Figure 2 [9], [10].

India has ample, untapped RE resources which include:

- The vast land area has the potential for solar energy generation. Moreover, solar exposure is also high in most of the areas of India.
- There are many zones and areas where wind velocities are high, which can lead to a significant amount of wind energy generation by both offshore and land-based wind farms.
- The decent amount of yearly biomass production.
- And India's precious asset of numerous rivers and waterways capable of a small hydel generation [14].

The primary reason for stressing to switch over to renewables is the energy crisis, alarmingly rising level of environmental pollution, and ever-increasing population, which contributes to a rapid increase in per-capita consumption, is greatly hindering India's economic and industrial growth. As of February 2020, total RE capacity in India stood at 86.76 GW in which the states Karnataka, Tamil Nadu, and Gujarat takes the significant shares in renewable energy production. Some of the other leading states are Maharashtra, Rajasthan, and Andhra Pradesh. However, few states don't have enough generation from RE compared to its potentialities due to lack of initiatives, absences of policy and regulation to promote RE intake. In some cases, the solar and wind energy generating plants were installed in the agricultural lands, which is beneficial. This trend of using agricultural land can have a significant improvement in the production of RE.

Installing solar panels above the crops and vegetation can create indirect sunlight to plants and help them to grow. At the same time, it also reduces the heating effect of the solar panels by retaining the humidity and moisture level below the panels [15]. GHG emissions from these agricultural fields produce hot air which can be utilized by the solar panel lying above the crops and helpful in generating electricity [16] thereby reducing the effects of GHG. Globally, the primary driving force of the energy sector in this decade is to adopt RE sources for energy generation and reduce the consumption of fossil fuels [17]–[19]. Because the damage cost caused by fossil fuels is unpredictable and in recent years, many countries have developed individual frameworks and policies, and it also has been adopted in practice to promote RE integration into the energy mix [20]. The hybrid systems such as PV-wind, PV- biomass, and so on were also emerging, which helps in increasing the overall production through RE [21]. India is a vast country with various states, and each has its unique approach and self-oriented policies in the renewable energy sector. Moreover, policymakers, utilities, stakeholders and researchers are working together to promote RE integration into the Indian energy mix to become the global leader in RE generation.

The paper mainly focuses on the progress of renewable energy growth in the leading three green energy-producing states of India in addition to the global and Indian renewable energy perspectives including initiatives and policy regulation to promote renewable energy integration into the energy mix. The primary concerns and improvement suggestions for other states are also highlighted. Nation-wide policy changes and barriers hindering the growth rate are also discussed. The pathway for India to become a global leader in RE generation is also suggested and concluded with the prospects of renewable energy growth in the country.

II. METHODOLOGY

Relevant information either from academic literature or grey literature is needed for conducting this sought of extensive review. A keyword search-based framework with the systematic process of organizing the data is used. In the first instance, thorough discussions are made to decide the keywords. Based on the discussions, the keywords are selected for data collection of academic and grey literature. Here, the academic literature involves the scientific articles published official journals and conferences, whereas the grey literature involves the technical reports, policy-related papers, and web resources. This study considered the most popular research database Web of Science (WoS). The keyword search covers all major indexing databases of WoS. While data collection, we ensured the searches would only consider the peer-reviewed articles from the WoS database. The searches for academic literature information resulted in thousands, but in the initial screening, around 860 articles are considered. These identified 860 articles were further pre-processed to find the most suitable articles for this review work, and the found non-suitable articles were eliminated. In the screening process, a total of 726 articles were eliminated. While screening the articles, a manual process is adopted to see the suitability of the articles for the review. After these, only 134 articles found to be most suitable and those were included as a part of academic literature. Grey literature related information is thoroughly identified in the technical reports of the relevant organizations, as official useful web resources of different organizations related to the government sector, private sector in the field of energy, environment, policy, and economic development. A total of 94 information sources used in grey literature, of which 33 are based on technical reports, and 61 based on web-resources. Overall, 228 documents have been used in this review process. The details of the systematic framework used in this review are shown in Figure 3.

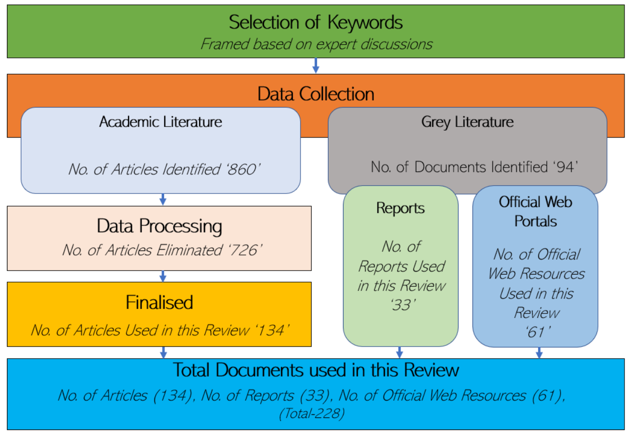

FIGURE 3. A systematic framework for data collection and finalization on academic and grey literature.

III. AN INTERNATIONAL ASPECT OF RENEWABLE ENERGY: STATUS AND POTENTIAL

United Nations SDGs act as guidelines and framework for countries to achieve a sustainable and better environment for everyone on the planet. The SDGs accelerate the steps to be addressed to overcome critical challenges and interconnects every goal for a better future, and the UN has fixed the deadline for every member nation to accomplish the goals by 2030 [2]. Goal 12 [22] of the SDGs emphasis the motto "doing more and better with less," energy efficiency, sustainable infrastructure, consumption, and production are the key areas that need to be addressed. While goal 7 [23] stresses affordable and clean energy for all, but global nations are facing various blocks in executing this practically. More progress needs to be made, and more public and private investments should be made. Moreover, innovative models and regulatory frameworks need to address to achieve this goal. About 17.5% of total final energy consumption [23] comes from renewable energy while remaining came from conventional sources. It indicates that fossil fuels comprise a significant part of energy production, which leads to a chain reaction of GHG emissions, global warming, and climate change effects. One of the primary objectives of the Paris agreement is to keep the global temperature rise less than 2 degrees Celsius [24]. It also aims to improve and aid nations in dealing with global climate change. The Agreement was different from its predecessors with its bottom-up approach; INDCs (Intended nationally determined contributions) for making it even more successful [25]. With about 197 countries signed

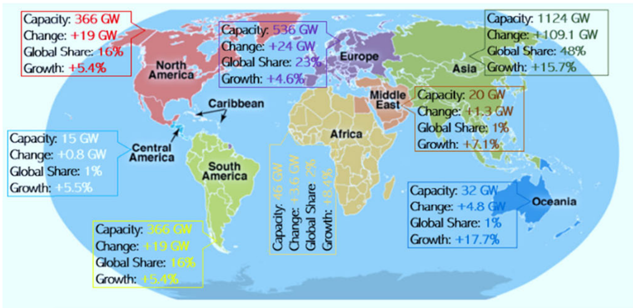

FIGURE 4. Renewable energy generation capacity at the regional level as on 2019 [31].

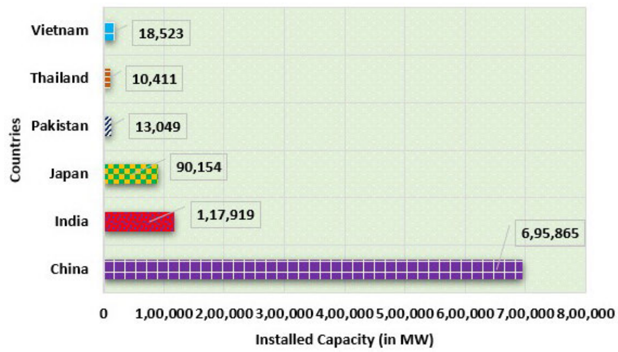

FIGURE 5. Total Installed Capacity of Leading RE producing Asian Countries as of 2018 [33].

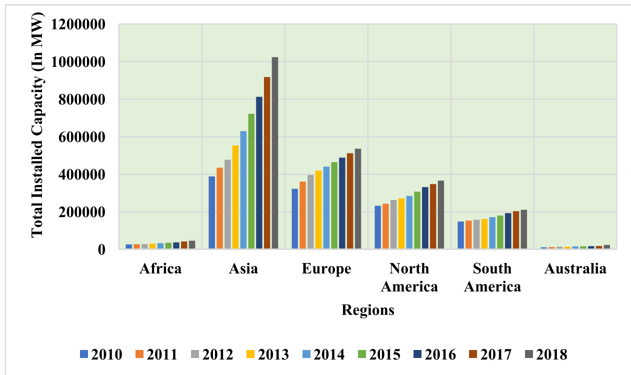

FIGURE 6. Total Renewable Energy Installed Capacity [31].

the Paris agreement as of November 2019, many of them have committed themselves towards the net-zero emission target. The Paris agreement acts as a catalyst in driving investments into cleaner energy and economy. India has also committed to reaching 40% of no-fossil fuel electricity by 2030 [26]. With 185 countries ratified the agreement; still, some are pending to ratify it. While the US intends to exit the accord by 2020, China has achieved its 2020 target in 2017 and countries like Sweden, Portugal, France had made the most progress with 77%, 66%, 65% respectively [27]. Therefore, the emerging interest today is to increase the share of renewables in global energy production to meet the ever-rising demand, reduce global warming and energy costs. Hence, significant initiatives are being taken to develop policies to increase renewable energy penetration into the energy mix, and over time, many countries have developed individual frameworks and policies [28], [29]. In recent years, many policies have adopted throughout the world in supporting renewable energy integration in the electricity sector such as 61 countries introducing a feed-in tariff (FIT) and the introduction of green certificates or auction systems with Europe leading implementation [13]. By 2017, policies for renewable power had spread to 121 countries. Global production of renewable energy is increasing day by day and in 2018; 171 GW renewable energy is integrated into the energy mix with an annual increase of 7.9 per cent by new additions from solar and wind energy [30]. Total RE installed capacity continent wise is shown in Figure 4 in which it is evident that Asia is the leading continent with a global share of 44%.

Among the Asian countries, China leads in renewable energy production followed by India and Japan. Figure 5 shows the Total RE Installed Capacities (in MW) of some of the leading Asian countries. From Figure 5, it is evident that China, the world's most populous nation and one of the largest renewable energy-producing nations achieving through its enormous potential in solar [32] and installed capacity in hydroelectric and wind energy. As of 2018, it has a RE installed capacity of 695.86 GW, which was six times greater than India's total installed RE capacity [33]. In the 13th Renewable energy five-year plan, China had set a target to achieve 680 GW of power generation from renewable energy sources by 2020, with wind energy accounting up to 210 GW [34]. But China, at the end of 2018, achieved a total installed capacity of 728 GW, which is a 12% year on year increase in all forms of renewable [35]. The Chinese government is also giving many incentives for local companies to support this development to reduce dependency on other countries [36]. Biomass capacity has considerably increased in recent years with total installed biomass capacity accounting for about 17.8 GW. Thus, China's new energy policy on self-security for energy takes proactive steps in developing cutting-edge technology in improving the efficiency of plants and delivering quality renewable energy and expansion of its various facilities across the nation.

Renewable energy growth in the region from 2010-2018 is shown in Figure 6. Various sources of RE generation in these regions as of 2018 are shown in Figure 7 [31]. In the North American Continent, countries like the United States, Canada, Mexico lead in renewable energy production, with the United States pioneering in all fronts with an installed RE capacity of about 245.24 GW as of 2018 [33]. The United States of America stands as the second-highest polluter in the world, with 14.6 % [37] of overall carbon emissions in the world, but it also manages to lead in RE production in the world only behind China. The United States of America has abundant resources and mainly has a more significant

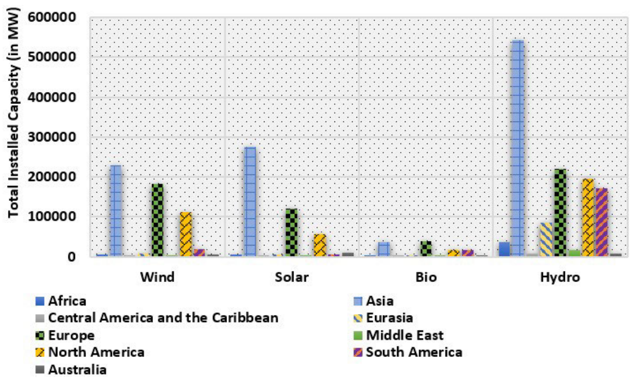

FIGURE 7. Resource-Wise Installed Capacity as of 2018 [31].

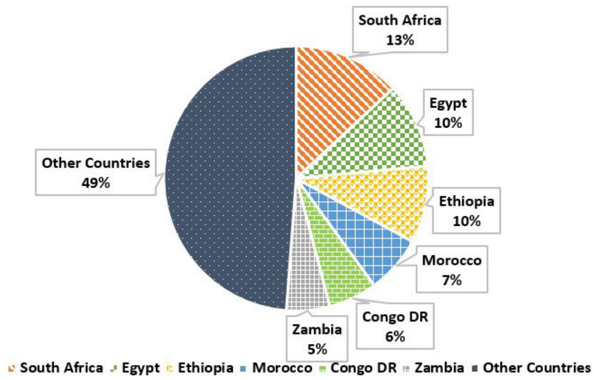

FIGURE 8. Total RE Installed Capacity of African countries in 2018 [45].

potential of wind energy, and the government is likely to invest resources to increase its total capacity of wind energy to 314 GW [38]. In recent years, interest in solar energy adoption in small scale production has been in rising with the initiative of many private players like SolarCity Corporation who tends to play a critical role in the wide-scale adoption of solar energy in US households. The share of renewable energy production through the solar, wind, geothermal and hydroelectric are projected to increase considerably in the next decades, with solar PV is projected to constitute about 48% of total renewable energy production followed by wind at 28% and hydroelectric at 18% by the end of 2050 [39]. The hydropower limited since there is a minor possibility of adding new structures. Renewable energy could also become the most abundant energy source contributing to about 50% by 2030.

In Europe, among various countries like Sweden, Finland, Portugal, Denmark, Germany, and France leads the renewable energy production in the continent. Sweden is considered for discussion as it is one of the pioneering countries which lead towards a low-carbon economy with nearly 60% of energy coming from RE sources [40]. It has an installed capacity of about 29.06 GW, according to a report by IRENA (International Renewable Energy Agency) [33]. It is a part of IEA (International Energy Agency) since 1974, and currently, the country has the second-lowest CO_2 emissions in the world [41] and which is about $1/4^{th}$ of the United States of America [42]. The country was able to achieve this feat only because most of its energy comes from nuclear and hydroelectric power, which is nearly emission-free. Its energy sector underwent considerable changes in the production of energy in the last 30 years. Though nuclear and conventional sources make a large part of the country's energy production, hydropower contributes a considerable amount of about 68.6 TWh (Terawatt hour) [43]. It enjoys a massive amount of water resources, but still, hydropower expansion remains narrow as part of safeguarding the remaining large rivers. The country has already achieved 50% RE in total energy production way back in 2012, and now it is on track to achieve 100% RE production by 2040 [44].

The total renewable energy installed capacity of the African continent stands at 46269 MW at the end of 2018 [45]. African countries like Ethiopia, Egypt, Morocco, South Africa leads the renewable energy production. RE installed capacities in some of the African countries are shown in Figure 8. South Africa is the pioneer regarding renewable energy production among the African countries, and the National Development Plan 2030 aims to make a decent investment in renewable energy capacity and generation [46]. The White paper on renewable energy (2003) was vital in stressing the needs of RE and the need for diverse energy generation mix in the country [47]. The nation has witnessed a rapid increase in recent years from a baseline zero RE capacity in 2010. South Africa Department of Energy (SADOE) has decided based on the new Integrated Resource Plan (IRP) focusing on increasing PV solar panels to reduce coal-fired plants and also not to install new nuclear power plants.

Under the Renewable Energy Independent Power Producer Procurement Program (REIPPP), 27 new renewable energy projects have signed, which will add about 19400 MW of new generation capacity by 2030 [48]. Many parts in South Africa on average, receives about 2500 hours of unobstructed sunshine throughout the year. The average solar radiation South Africa receives is about 4.5 and 6.5 kWh/m2 [49]. Currently, Rooftop solar PV installed capacity is about 250 MW [50]. Wind energy generation is also considered from several wind farms like Metrowin Van Stadens (27 MW), Jeffreys Bay (138 MW), Kouga wind farms. It also has a higher potential for biogas production with an estimation potential of 2500 MW of power. Though renewable energy production is acute, the government aims to adopt various RE sources and to gradually reduce coal consumption with an ambitious target of 21.5 GW of RE capacities by 2030. It includes 9200 MW Wind, 8400 MW Solar PV, and 1200 MW of solar CSP (Concentrated Solar Power) capacity.

India has fast-tracked its approach in adopting renewable energy, gaining necessary experience from global countries regarding how to accommodate feed-in tariffs, net metering, attracting stakeholders to promote renewable energy, and have adopted national policies. Many states in India have

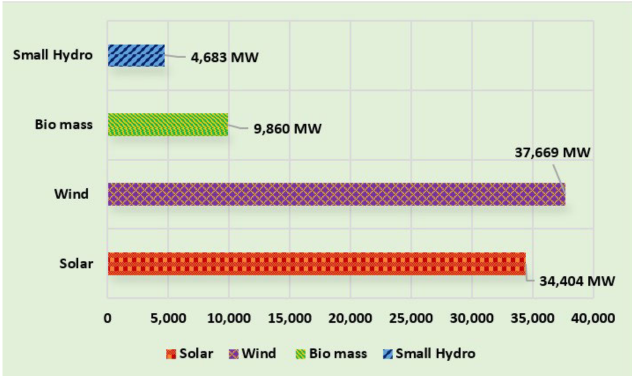

FIGURE 9. Installed Renewable Energy capacity in India as on 29th February 2020 [51].

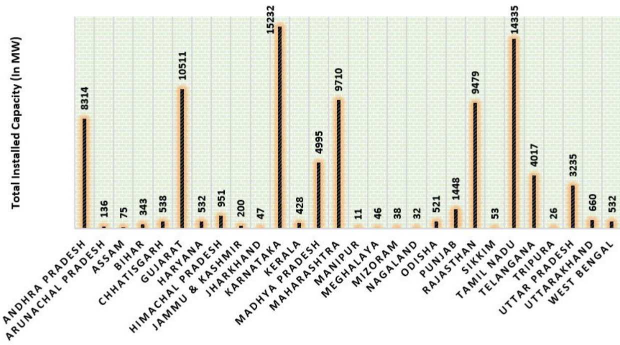

FIGURE 10. India's state-wise RE generation in MW as on 29th February 2020 [51].

also drafted separate policies for both grid-connected and off-grid renewable energy, which will be discussed in later sections.

IV. INDIAN RENEWABLE ENERGY SCENARIO

India is continuously improving and keeps setting regular targets for embracing RE to curtail ever-increasing carbon emissions as well as global warming and improve air quality index. Moreover, India's energy consumption is set to considerably escalate in upcoming years as the Indian government has destined to drastically scale down the production of traditional vehicles and streamline to adopt the electric vehicles by 2025.

India has adopted many policies to promote renewable energy generation throughout the country though it is not distributed uniformly. The International Energy Agency (IEA) proposed that India will be the 2nd most significant contributor to global energy demand by 2035. From the results of load forecasting, it is clear that the demand of 90000 MW should be met to fulfil the basic electrical needs in 2035. In the initial stages of development, the photovoltaic (PV) cells are costlier and resulted in lower efficiency compared to non-renewable energy. As years passed an exponential decline has been noticed in the prices of PV technologies. About 80% drop in its cost is observed, which encouraged switching to PV resources for electricity generation [52]. As a result of Electricity Act 2003, almost 17 states in India have formulated policies of inviting the private sectors for uplifting the RE generation and which also allowed wheeling, banking and bay-back of electricity. All these are done to attract private sectors. The term 'wheeling' refers to the transmission of power from a seller to a buyer through the network owned by the third party. The 'Bay back' refers to selling the excess electricity generated from PV or any other RE resources [53]. Some states are way above in generation capacity compare to many other states. Figure 9 shows the total installed capacity of RE in India. The data has been adopted from the Ministry of New and Renewable Energy (MNRE) report, which was uploaded on 29th February 2020.

India's state-wise RE generation is shown in Figure 10 in which it was evident that out of the 29 states, only 10 states have RE generation of more 1000 MW. From Figure 9 it was evident that the solar and wind energy generation leads the total RE generation in India, so considering energy generation through these two resources Table 1 is formed which comprises generation of all 29 states of the country. The Indian states are classified into northeastern, southern, northern, western, central and eastern states depending on the location of each state. After the keen observation and analyzing the table, it is clear that northeastern states have a deficient generation and the generation through the wind in these states is 0 MW. All the states in the north-eastern region of India have very minimal RE generation, where most of it comes from a small-scale hydro plant. The main reason for their low production is the climatic conditions as well as the limited area and the geographical location. The generation through solar and wind energy is meagre because of the climate which is cold throughout the year and will receive a dominants rain in even summers.

Therefore, solar exposure and wind speed are not enough and economically sustainable to produce a large amount of solar and wind energy. The highest temperature these states receive is a maximum of 30 degrees Celsius [54]. On the other hand, North East India receives the highest rainfall with a mean annual of 11,418 mm. Reason for the small hydropower generation in all these states is the heavy rain throughout the year and a sufficient number of rivers to support through their potential for a generation. The smallest RE generation state in the country in Goa. This is because the state has the smallest area, which is not adequate to set any plant. However, the state is near the coast and has several beaches, so the generation through tides and waves can be adopted. But due to the insufficient budget and policies in the state, this is not yet lightened up.

From Table 1, the generation through solar and wind is high in southern states. The considerable generation is due to its favourable climatic conditions of the states and the policies formulated by the government. There are separate organizations in each state to continuously monitor and promote the RE by introducing new policies and awareness. The

TABLE 1. Represent the total installed capacity of solar and wind energy generation in the Indian States.

S.no	State	Solar energy (MW)	Wind energy (MW)	Total (MW)
	NORTHEASTERN STATES			
1.	Assam	41.23	-	41.23
2.	Sikkim	0.07	-	0.07
3.	Manipur	5.16	-	5.16
4.	Meghalaya	0.12	-	0.12
5.	Arunachal Pradesh	5.61	-	5.61
6.	Nagaland	1.00	-	1.00
7.	Mizoram	1.52	-	1.52
8.	Tripura	9.41	-	9.41
	TOTAL (MW)	64.12	0	64.12
	SOUTHERN STATES			
9.	Andhra Pradesh	3559.02	4092.45	7651.47
10.	Karnataka	7277.93	4790.60	12068.53
11.	Kerala	142.23	62.50	204.73
12.	Tamil Nadu	3915.88	9292.34	13208.22
13.	Telangana	3620.75	128.10	3748.85
	TOTAL (MW)	18515.81	18365.99	36881.80
	NORTHERN STATES			
14.	Haryana	252.14	-	252.14
15.	Himachal Pradesh	32.93	-	32.93
16.	Jammu and Kashmir	19.30	-	19.30
17.	Punjab	947.10	-	947.10
18.	Rajasthan	5035.08	4299.72	9334.80
19.	Uttar Pradesh	1095.10	-	1045.10
20.	Uttarakhand	315.90	-	315.90
	TOTAL (MW)	7697.55	4299.72	11997.27
	WESTERN STATES			
21.	Goa	4.78	-	4.78
22.	Gujarat	2886.16	7479.02	10,365.2
23.	Maharashtra	1801.80	5000.33	6802.13
	TOTAL (MW)	4692.74	12479.35	17172.09
	CENTRAL STATES			
24.	Chhattisgarh	231.35	-	231.35
25.	Madhya Pradesh	2258.46	2519.89	4778.35
	TOTAL (MW)	2489.81	2519.89	5009.70
	EASTERN STATES			
26.	Bihar	151.57	-	151.57
27.	Jharkhand	38.40	-	38.40
28.	Orissa	397.84	-	397.84
29.	West Bengal	114.46	-	114.46
	TOTAL (MW)	702.27	0	702.27

organizations are New & Renewable Energy Development Corporation of Andhra Pradesh Ltd. (NREDCAP), Telangana State Renewable Energy Development Corporation Ltd. (TSREDCO), Agency for New and Renewable Energy Research and Technology (ANERT) which was established by the government of Kerala, Tamil Nadu Energy Development Agency (TEDA) and Karnataka Renewable Energy Development Ltd. (KRED) [55]–[58]

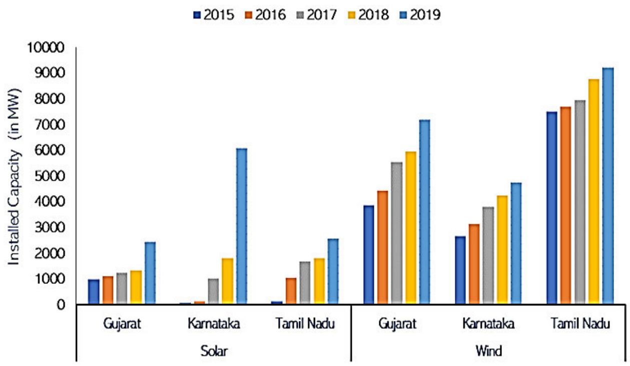

FIGURE 11. Solar and Wind Energy Installation in the top three states in India (2015-2019) [51], [53], [54].

From Table 1, it is seen that many of the states the generation through wind is negligible MW. The barriers faced by India in generating energy through wind are high initial costs, support instruments with inadequate designs, lack of access to capital for the financing of wind farms, lack of recent, detailed and accurate wind data, the underdeveloped home wind industry, high-interest rates on loans for setting up a wind farm, time-consuming procedures to get construction and grid connection approvals, lack efforts taken by R&D, insufficient transmission infrastructure and lack of good turbine designs [59]. These barriers are the reason for the deficient wind energy generation. Despite these barriers, some states Andhra Pradesh, Karnataka, Tamil Nadu, Gujarat, Rajasthan, and Maharashtra generate electricity above 4000 MW through wind energy. The reason behind this is the favourable wind speed in those locations and the introduction of policies by the state/local government like repowering policy, offshore wind energy policy, wind bidding scheme [60].

As of February 2020, the total RE capacity in India stood at 86.76 GW. The installed capacity of off-grid renewable power has also increased. Out of the total installed capacity in India, the states Karnataka, Tamil Nadu and Gujarat are pioneering in renewable energy production. The total renewable energy installed capacity (solar, wind, small hydro, biogas) of the three most prominent states Karnataka, Tamil Nadu and Gujarat are 15232 MW, 14335 MW, and 10511 MW respectively [51]. Figure 11 shows the solar and wind energy installation from 2015 to 2019 in those three states, while Figure 12 shows the current RE installed capacity. Therefore, in this section, the three prominent states of India were chosen to present the RE context of those states that were scrutinized and explained inclusively. The developments in each state, the plants in each RE sector and the policies of each state were analyzed.

A. KARNATAKA

Karnataka spread over an area of 191,791 square km and stands as the 7th largest state in India. It is in the southwestern region, and it shares its western border with the Arabian Sea and the Laccadive Sea [64]. There are four topographic

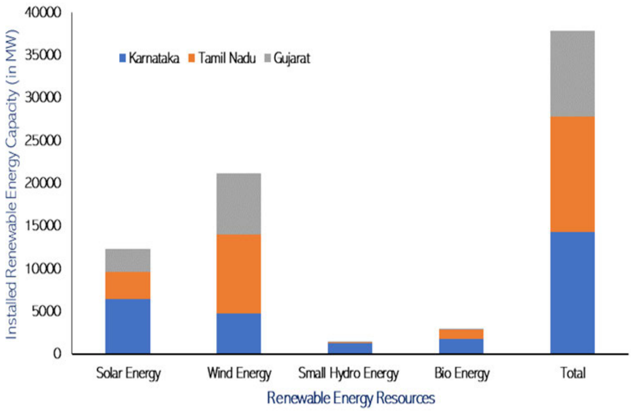

FIGURE 12. Installed Renewable Energy Capacity in the top three states in India [Data is from ref. 51].

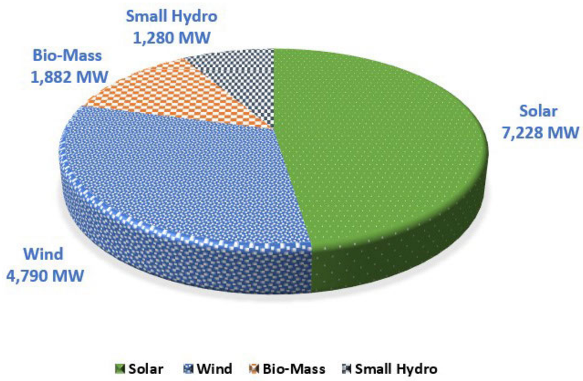

FIGURE 13. Composition of Installed Renewable energy capacity in Karnataka as on 29th February 2020 [51].

regions by which the state has been divided as Northern Karnataka Plateau, Southern Karnataka Plateau, Karnataka Coastal Region and Central Karnataka Plateau [65]. The state has toppled Tamil Nadu to become India's biggest renewable power producer with an installed capacity of 15.23 GW, and this includes 7.27 GW of solar, 4.78 GW of wind, 1.882 GW of biomass and 1.28 GW of small hydropower plants as shown in Figure 13 [51]. In the last two years, Karnataka has reached the first position in the production of renewable energy and the main reason is its policies and completion of the projects before the target. One of the most important moves taken by the government in collaborating with farmers to lease their lands for solar and wind power generation plants. At the same time, it is growing faster in biomass generation compared with other states.

1) SOLAR ENERGY

Karnataka is glorified with solar insolation for about 300 days in a year [66]. The state has made an accomplishment by installing high-density solar panels which receive high solar energy about 2000 to 2500 kilowatt-hours per square meter. The Shakti Sthala power plant located in Pavagada at Tumakuru district was launched in the year 2018 generated 2000 MW of energy. The solar park stretches across five villages, and about Rs.165000 million have been invested in installing this plant. This plant produces electricity to power approximately 700,000 households [67]. The development was initiated with the creation of the Karnataka Solar Power Development Corporation Limited (KSPDCL) as a deal that connects the solar energy corporation of India and Karnataka Renewable Energy Development Limited (KREDL). The favourable policies have also enabled large corporates to buy a significant proportion of their power from solar farms to supply grids under long term contracts with solar developers [68]. CleanMax, one of the private sectors, has installed 145 MW solar farms in Sedam village in Gulbarga district in Karnataka. The speciality of this project is that it came into operation within four months of commencement of its installation work. And this encourages the corporates to shift over to green solar power at low risk and zero capital expenditure [69]. The governmental sectors, as well as the industries, are reassuring to use solar-based heaters, air conditioners, and air heating plants.

2) WIND ENERGY

The State of Karnataka is rich in wind farm potentials, and the state's present total installed capacity is of 4790.60 MW. The Karnataka Renewable Energy Development Limited (KREDL) is facilitating agency for implementing renewable energy sources. For a suitable location of wind farms, the average mean wind speed is considered, and if it is greater than 5.4 m/s, it is a suitable and economically viable location for the situation of a wind farm, if it is less than 5.4, then wind speed is poor, and it is not economical to construct a wind farm in that particular area [70]. Tuppadahalli onshore wind farm is a 56.1 MW plant whose output is about 140 GWh per annum, and the other two wind farms in the state are Anabaru with a capacity of 16.5 MW and Arasinagundi with an installed capacity of 13.2 MW. In these wind farms, each turbine has a rotor diameter of 82 m and a hub height of 78m [71].

3) SMALL HYDEL ENERGY

Karnataka is accounted for 6 per cent of India's water resources, and hence it has a large surface of water potential. The state is blessed with seven rivers which include Godavari, Cauvery, Krishna and West flowing rivers accompanying their tributaries flow through the state. These rivers act as the source of hydropower [72]. Out of 939 small hydel plants in India, 132 projects are located in Karnataka. Due to this made Karnataka as one of the states with the highest number of existing plants [73]. There are nearly 20 dams in the state where water can be stored, and these hydropower projects can be constructed based on the availability of the head, catchment basin, and water flow. 1230.73 MW of capacity, which includes 15 small hydropower projects which are all in operation [74].

4) BIOMASS ENERGY

Biomass energy is a form of energy that can be extracted from living or decaying plants and animals, logging waste, agricultural waste, animal waste, industrial waste, and so on [75]. The fuels are gleaned from them, this chemical energy is released as heat when the biomass is burned, and this heat is used to provide electricity on a small scale. The wood and paper product industries in Karnataka found a good alternative to produce their electricity by combustion of these woods, thereby saving their money and eliminating disposal problems [76]. To overcome the electrical demands in the district of Tumkur, an organization named Biomass Energy for Rural India has implemented a gasification-based power generation project. The venture consists of six gasifier plants which include 100 KW and 200 KW plants and the power plants at Seebinayana Palya and Boregunte in Tumkur district of Karnataka are called the twin biomass power plants, each has a capacity of 240 KW. The main objective of constructing these plants is to reduce greenhouse gas (GHG) emissions and to fulfil the essentials in backwoods [77].

5) TIDAL ENERGY

Karnataka is enthroned with 320 Km seaside integuments Dakshina Kannada, Udupi and Uttara Kannada. The testimony from Resource and Development (R&D) to field positions is being aided with a motive of endowing a model that demonstrates the production of energy through the waves [78]. In 2017, ANR Techno Powers Private Ltd submitted a project report to the state government to set up a 10MW tidal power plant for generating power through waves of the sea at Maravanthe beach, but this was not yet sanctioned [79]. The potential energy per meter sq. in Karnataka is 0.2 MW, but due to the limited tidal energy policies in the state as well as the country, the utilization of the seashore area is not enlightened. The huge capital investments, coupled with a high maintenance cost, are the hindrance to choosing this system [80].

B. TAMILNADU

Tamil Nadu is situated in the southern region, covering an area of 130,058 square km. The states Kerala, Karnataka, Andhra Pradesh, are bordering Tamil Nadu. As the state is present in the bottom tip of the country it is enclosed by the Indian Ocean, the Arabian Sea and the Bay of Bengal [82], the State was gifted with plenty resources and its Government has set up a separate department called Tamil Nadu Energy Development Agency (TEDA) in 1985 [83], to promote the progress of non-conventional energy and assuage climate effects by bringing out conducive policies. Figure 14 shows the total installed capacity through different RE resources in Tamil Nadu.

1) SOLAR ENERGY

Solar power is most abundantly available in Tamil Nadu with the established capacity of 3915.88 MW in the state. The 1MW grid-connected solar PV power plant has been installed in southern regions of the state [84]. Kamuthi Solar Power Project is the biggest single-location solar power plant that spans over an area of 2500 acres comprising 2.5 million solar modules, which can produce about 648 MW of energy

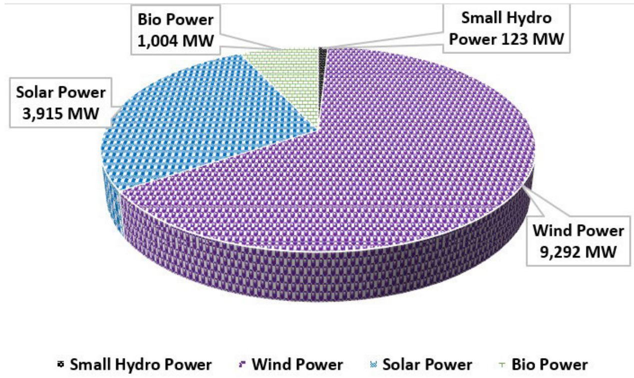

FIGURE 14. The total installed capacity of Renewable energy in Tamil Nadu as on 29th February 2020 [51].

[85]. The state government has come up with Solar Energy Policy 2019, which intends to generate about 9000 MW by 2022 [86]. In addition to these projects, the Solar Powered Greenhouse scheme and the MNRE Capital subsidy scheme for providing financial incentives for rooftop and off-grid solar plants helps in boosting the solar energy production in the state [87].

2) WIND ENERGY

The Tamil Nadu is blessed with most windy sites in the country as it is near the coastal regions. The state has experienced a speedy response from the private sector since the emergence of wind power in the country. The vigorous wind at a speed of 5-6.67 m/s was seen in the southern districts. The wind power generation capacity is 8764.34 MW. The state not only develops wind farms, but it also manufactures wind turbines. It was started as a combined project between NEPC of India and Micon of Denmark. The state has succeeded in installing 1083MW of wind energy in the single year of 2011, which is the highest annual installation by any state in the country in a year [88]. The growth of wind energy is also seen in the districts of Coimbatore, Tirupur, and Theni, where the maximum turbines were being installed. The Muppandal wind farm located in the Kanyakumari district is India's largest operational onshore wind farm [89]. The total capacity of about 1500 MW with 3000 windmills was present on this farm, which represents the largest concentration of wind farms at a single location [90]. Till 1996, the growth in this field is low, but improvements are made in technology which led to the installation of Asia's biggest wind turbine with the capacity of 2MW at Chettikuloam near Koodankulam in Tamil Nadu in 2004 [91]. In 2015, MNRE approved the National Offshore Wind Energy Policy, and this led to the resource assessment in the shorelines of Gujarat and Tamil Nadu. By considering various technical factors, the selection of zones, to set up a wind farm of 150 MW and 504 MW, a plan has been designed, and the pre-feasibility test was conducted. Offshore wind farm development is also prominent in the state [92].

3) SMALL HYDEL ENERGY

The State of Tamil Nadu has been classified as one of the Medium potential states in small hydel plant (SHP) production [93]. Though the energy contributed by small hydro is very negligible considering the total renewable energy production in the state, but it has a sizeable of energy in the future as only about 19 % of SHP has been installed by the states. Still, projects are to be implemented for about 660 MW; as of now, installed capacity stands as 123.05 MW [94]. On 28th August 2016, TANGEDCO approved the Kollimalai hydro-electric project of capacity 20 MW in Puliancholai village at Namakkal district. The massive sum of Rs.3387.9 million is funded for the project, and it is expected to be commissioned by April 2021 [95]. Most of the Small hydel power plants are maintained by the state, except one small hydro project managed by the private sector. Under the river scheme, an association named TANGEDCO has planned to establish the project in this domain whose generation capacity is beneath 25 MW.

4) BIOMASS ENERGY

Till now in the state, the biomass energy generation is not to the full extent, and the generation through this is possible in the upcoming years. The total biomass potential comprises of Agro-residue and Forest and wasteland residue for production, producing around 1589.9 MW of bioenergy [96]. The Agro-residue plays an extensive production of bioenergy, it spans over an area of 4165.3 hectares with biomass generation of about 22507.9 tons/Yr., and power potential of 1159.8 MW. However, forest and wasteland residue produce a 430 MW potential of bioenergy. TEDA has actively involved in promoting generation through a large scale in specific areas with high potential crops through Tamil Nadu Biomass Power Producers Association [97]. The total biomass energy capacity generated is the sum of the capacity generated through the biomass-based cogeneration fuel plants, biomass gasification plants, bio methanation plants, and vegetable waste-based power plants. All these plants as a whole contribute to biomass energy production in the state [98].

C. GUJARAT

Gujarat is called the "Jewel of Western India." It is a land of vast plains, rivers, hilly regions, and gulf. The state is surrounded by Indian Peninsula on western coasts, and the borders of Pakistan and the state of Rajasthan in the north-east and Madhya Pradesh lies on the east and Maharashtra in the south and along with some of the union territories [102]. As of February 2020, the total installed capacity in renewable energy is 10511.43 MW which is shown in Figure 15 [51]. The reason behind why the state has an enormous generation is because it has a good percentage of barren lands with a good wind flow, which has been utilized to the maximum extent to install solar and wind plants.

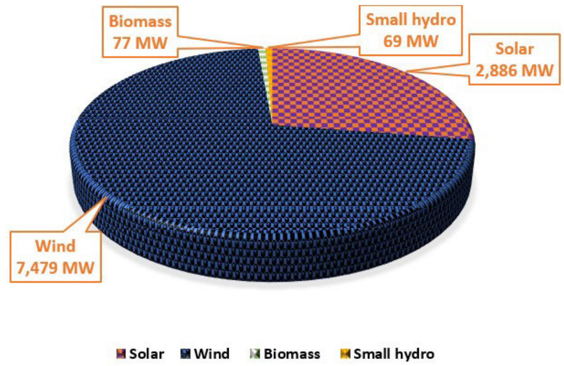

FIGURE 15. The Total Installed capacity of Renewable energy in Gujarat as on 29th February 2020 [51].

1) SOLAR ENERGY

Solar power projects are blooming in Gujarat and had massive growth. The small part of the Junagarh district has constrained to have a maximum solar energy generation. And Gujarat has fewer monsoon effects compared to other states in India, so cosmic energy generation is altered in August [103]. The Gujarat Solar Park 1, which is also known as Charanka Solar Park, is one of Asia's biggest solar parks located at Patan district in Northern Gujarat and spread across 5.382 acres of unused lands. The total capacity of the solar park is 500 MW. More than Rs. 12 billion has been invested in the solar park by financial institutions [104]. The park is presented as a contemporary and environmental-friendly plan by the Confederation of Indian Industry [105]. Solar power plants are located at multiple locations in the Surat with a combined capacity of 1 MW. They are powering three water distribution plants and 18 municipal schools. The Surat Municipal Corporation is independent of the electricity companies for water distribution because they have completely shifted to use power generated from solar plants [106]. The Gujarat Energy Development Agency (GDEA) had set a target of achieving at least 50MW from rooftop solar plants in upcoming years. An innovative idea of installing the solar power plant on the canal top has been launched in Gujarat to set up the solar panel's long branches of Narmada canals, which travels to a distance of 19000 kilometres were being used [107]. This project has been commissioned by SunEdison India.

2) WIND ENERGY

The state has a littoral of 1600 km where the wind velocity is sufficient for electricity generation. The open lands are available throughout the coastline, where the installation of a wind farm is possible. Therefore, this sector has a major importance in the state [108]. Due to the efforts of government, in 1985, India's first joint sector with a capacity of 1.10MW of wind energy was installed at Mandvi [88]. The government was investing massively in wind power and spotted Samana in Rajkot district as a suitable area for the establishment of 450 turbines that can produce a capacity of 360MW. ONGC Ltd. has installed a 51 MW wind energy farm at Bhuj in Gujarat. ONGC has set a target of 200 MW for the development of wind power capacity [88]. The current trend in the state is offshore wind energy generation and establishing related to this and MNRE is supporting them by setting up a team to conduct studies on the potential of off-shore wind energy and if everything favours then an offshore plant will be established soon. It is suggested that a possible potential of 1 GW capacity plant can be set at the coastline of Gujarat. The country has made advancements by analyzing 8 zones on the coast of Tamil Nadu and Gujarat. An analysis is done by long term measurement of offshore potential so that a correct prediction and identification of zones can be made more efficiently as per the off-shore policy [60].

3) SMALL HYDEL ENERGY

The state of Gujarat has many rivers, streams, and large canal networks that have the abundant potential for the production of clean, renewable energy through small, micro and mini-projects [109]. Gujarat has an estimated potential of 202MW [110] of generation, but only 35MW has been successfully tapped. The Gujarat Small Hydel Policy-2016 was framed to provide an extensive protocol for aggressively promoting and adopting the small hydel projects to exploit its maximum potential in the state [109].

4) BIOMASS ENERGY

As many as 37 locations have been identified across Gujarat, which has a potential surplus of biomass where the plants can be set up. The first biomass power plant was started in Sankheda taluka of Vadodara district has been set up by Ankur Scientific Energy Technologies Pvt Ltd based on gasification technology. The project was completed in 6 months with the help of local villages and farmers, panchayats, taluk offices, GDEA and MNRE. The cost of the project is Rs.6.4067 million, including construction, land, and machinery [111]. Junagarh Power project had set up a plant capacity of 10MW at Khokharda village [112]. Nitash Co-generation Pvt Ltd has inaugurated a Cogeneration power plant at Dharikheda in the Narmada district with 67.7MW capacity [113].

5) TIDAL ENERGY

Gujarat is the first state in India to initiate generation from waves, and the locations were found in the Gulf of Kutch and Gulf of Cambay on the west coast, where there is huge tidal potential with a tidal range of 8m to 11 m as shown in Figure 16. The potential in the Gulf of Cambay is 7000MW, and in the Gulf of Kutch, it is about 1200 MW [114]. In 2011, Gujarat approved the construction of 50MW plant in Gulf of Kutch, and in the same year, MNRE has announced to provide financial support as much as 50% of the cost for the demonstration of the project. In 2012, Atlantis Resources, a British tidal energy company, has approached the government to install a plant in Kutch with a capability to generate 50MW at the cost of Rs. 25 billion. If the project is successful, then it will be extended to 200MW. The installation of this kind of technology can be started in the fullest form in the upcoming years [80], [115].

FIGURE 16. Gulf of Kutch and Gulf of Cambay [116].

6) GEOTHERMAL ENERGY

Geothermal plants extensively use hydrothermal resources which have both water and heat located within 3km of earth's surface, which is used to drive a heat engine. Deploying energy from this technique will have many challenges [117]. The considerable survey has been done for potential exploration and exploitation of geothermal energy. In India, about 340 hot springs were found in existence by the geological survey, and they are scattered in seven geothermal zones. They were found running from the west coast to the western border of Bangladesh, which was known as SONATA and along the west coast in Gujarat and Rajasthan [8]. In Gujarat, Dholera is located about 30 km away in Ahmedabad district is one of the potential sites for tapping geothermal energy [118].

V. INITIATIVES TAKEN FOR RENEWABLE ENERGY PROGRESS

In India, these three states stood as a pillar to support the generation through RE, and they are the reason for the massive development in RE potential in the past two decades. And these states are working to fulfil India's target of 175 GW generation from RE sources by 2022. Initiatives taken by the three states are given below:

A. KARNATAKA

- By 2020, the government of Karnataka ensures to provide the 24∗7 electricity for all places in the state. As of 2017, 29 villages in Karnataka are yet to get power supply. Karnataka Renewable Energy Development Limited (KREDL) is established to boost-up the generation of electricity through renewable energy [81].
- The government issued "KREDL 2009- 2014" to improvise and utilize the generated energy in a productive manner. During five years of the program, the policy action has a target to achieve about 1970 MW.

- To assist the progress of the project regarding the finance and energy conservation, a Green Energy Fund, which was named as "Akshaya Shakthi Nidhi" has been reported by KDREL [81].
- Solar cities were being developed in the state.
- As per the MNRE scheme, municipal corporations of Mysore and Hubli Dharwad have been chosen to turn them into a developed solar metropolis.
- As per the rules and regulations of the government, the lands will be leased to the RE developers for a period as long as 30 years for the installation of the renewable energy plant.

B. TAMILNADU

- TEDA established on 29th November 1984 encourages energy maintenance and make everyone to switch to RE, thereby implementing new projects. TEDA also encourages research and developments to promote the RE sector [83].
- The state has applied various schemes proposed by the plan titled National Action Plan on Climate Change (NAPCC) to improve production.
- The Tamil Nadu Power Finance and Infrastructure Development Corporation Limited have been formed to provide loans to set up wind farms. In some cases, the loans were also provided by IREDA for promoting biomass projects [99].
- The government has announced its "Solar Energy Policy-2019" intending to install about 9000 MW capacity by 2023 and declared that the consumer encouraging solar power would be free from electricity tax for 2 years. The state conducted many awareness programs to promote solar and wind energy in agricultural sectors [100].
- MNRE is promoting waste to energy projects through 2 schemes-one is the energy improvement from metropolitan and industrial wastes, which was a national level program and the other one is the United National Development Programme (UNDP). There are assisted projects which concentrate on the tremendous rate of bio methanation processes, thereby decreasing GHG emission [101].

C. GUJARAT

- Gujarat Energy Development Agency (GDEA) offers a subsidy for rooftop solar of Rs.10,000 per KW of installed capacity up to a maximum of Rs.20,000 per customer [119].
- "Small scale distribution solar project-2019" policy has been started by the state. The policy is about installing a solar project with generation capability between 500 KW to 4 MW. It will lead to setting up of solar photovoltaic projects in scattered pockets of barren and uncultivable land at a fast pace. The policy will provide visibility to small developers in terms of available tariffs for the sale of power and help promote small-scale entrepreneurs. The power produced will be directly fed into the 11 KW line of Gujarat Energy Transmission Company Limited (GETCO) [120].
- Gujarat hybrid power policy (2018) aims to scale up the installation of wind and solar hybrid power projects to minimize the variability apart from optimally utilizing the required infrastructure including land and transmission systems [121].

VI. COMPARISON OF THE RENEWABLE ENERGY SCENARIO BETWEEN THREE PIONEER INDIAN STATES

This section gives an overview of how each state is different from others in a comparative method. Each RE resource and its various leading factors in each state have been compared. Table 2 gives a detailed overview of the various highlights of each state in the specific RE sector separately. It gives a quick glimpse of how each state is different from the other in their policies and generating approaches.

VII. BARRIERS OF RENEWABLE ENERGY IN INDIA

Renewable energy has seen a considerable rise in the past decade but still a long way to go to achieve the full level of its potential. One of the main reasons for the slow development of RE in any country is the lack of proper awareness about it to the public. Other barriers/constraints to promote renewable energy are national and international policies, availability of land space for RE plants, political and social awareness, and financial and technical considerations. The government and other private energy agencies should bring a general awareness as well as policies about it and stress for the economic consumption of energy. In this section, some of the significant barriers, including; economic and financial barriers, technological, institutional, industrial, political, regulatory and environmental, were perceived and reviewed in Table 3.

VIII. RENEWABLE ENERGY POLICIES OF THE CENTRAL GOVERNMENT OF INDIA

The barriers which have been discussed in the preceding section can be vanquished by taking initiatives regarding policymaking and financial investments. The present section discusses the policies and plans which the Indian government has formulated to promote renewable energy.

Country's three-fifths of power generation is based on fossil fuels, and the country faced hurdles due to the impacts of generation through fossil fuels which introduce global warming. In the last few decades, the regime has formulated many steps in cultivating the generation through renewable energy, thereby decreasing the use of fossil fuel-based energy. The Ministry of New and Renewable Energy (MNRE) is a department that takes charge of official matters and helps in uplifting the RE resources [193].

The State Electricity Regulatory Commissions (SERCs) specified better tariffs for purchasing renewable energy. There was no eminent cooperation from the private sector, but there existed some national actions to uplift the power generation through RE resources. In 1991, after the annunciation

TABLE 2. Detailed comparison of various sources of renewables for the studied three states.

Renewable energy sources	Comparison between states on various factors
Wind energy	-Wind power is the best competitor of fossil fuels and with 27 % annual growth, which confirms that it is doubling its installed capacity every three years [122]. -Tamil Nadu leads wind energy generation in India. The total installed capacity is 9127.22 MW [123], while Gujarat stands second with a capacity of 6102.67 MW, and Karnataka stands 4th with a total capacity of 4694.90 MW. -In June to September, about 80% of wind energy is generated in Tamil Nadu and Karnataka [93]. The primary reason behind Tamil Nadu harnessing a large amount of wind power than other states is due to its suitable location [124]. -Gujarat has the advantage of south-west wind originating from the Arabian sea with an average wind speed of 8 m/s [125] while Tamil Nadu due to the chain of mountainous ranges in the western Ghats leading to the concurrent blowing of wind for almost 9 months in a year at Muppandal with an average wind speed of 5-7 m/s [109], making it suitable for generating electricity [126]. -As of 2014, the Muppandal wind farm is the largest wind power plant in the country with a generation capacity of 1500 MW located in Tamil Nadu while Tuppadahalli onshore wind farm with a generation capacity of 56.1MW, is the largest wind farm in the state of Karnataka and Kutch Wind Farm is the largest in Gujarat with a generation capacity of 1100MW [127]. -The current Tariff Rates [128] for wind energy generation in Tamil Nadu is at 3.51 Rs/kWh, and Karnataka, the tariff is at 3.70 Rs/kWh, while Gujarat is the most expensive at 4.23 Rs/kWh.
Solar energy	-Solar energy generation is one of the most promising hybrid technologies [129]. For promote the advancement of solar power, Jawaharlal Nehru National Solar Mission (JNNSM) was launched by the Government of India during 2010-2011. Initially, the government has a target of implementing grid-connected solar power of 20,000 MW by 2020, but in 2015 this target was updated to 100000 MW. The introduction of this project has increased the installation capacity of the three states [130]. -The roof-top PV air collectors are widely used, and these could utilize the incident solar insolation's falling on it and convert into electricity and useful heat [131]. It was encouraged in the State of Gujarat at starting and it has started the Gujarat solar power policy 2015, which has contributed 69MW of the total roof-top solar project, whereas Karnataka has contributed about 51 MW of total roof-top solar project and the contribution made by Tamil Nadu, is very high, it is about 132 MW. There is no payment regarding the cost of power for net export in Tamil Nadu, whereas Karnataka and Gujarat have some charges [132]. -Till 2014, Gujarat stands as one of the leading solar photovoltaic generating states in India along with Rajasthan with a total installed capacity of 919 MW in Gujarat, whereas in Tamil Nadu it is 100 MW [133]. -MNRE has launched Solar City Program in 2008, which aims at enabling the government to work with Urban Local Bodies to look into the energy challenges faced by cities and thereby finding a way to reduce the demand for traditional energy by 10%. The cities Rajkot, Gandhinagar, Surat from Gujarat and Mysore from Karnataka were proposed for development with a Solar city master plan [134]. -The 3 states have mandated that in the specified category of buildings, installation of rooftop PV panels as mandatory. According to the study by Ramachandra et al. (2011), the states Karnataka, Tamil Nadu, and Gujarat receive annual global insolation of more than 5 KWh/m2 per day. -Gujarat Power Corporation Limited (GPCL) has implemented a 1 MW canal top Solar Power Project in Gujarat. This idea of the solar panel over dams and canals in Gujarat is astonishing, and it helps in the reduction of water evaporation due to heat and radiation and results in reducing the impacts due to climatic changes [135]. -One of the most reliable ideas of Tamil Nadu is the solar street lighting scheme, which includes 20 W LEDs for 100 thousand street lights with a feature of auto-dimming 6W at a particular interval of time along with other options like 5-year replacement warranty for remote monitoring [136]. This approach is also started to implement in other states. -The state Karnataka is developing the world's largest solar park in Tumkur district to produce 2000 MW of solar power. And for irrigation, the MNRE has approved a system of 9725 number of solar water pumps, in which 5506 are operating under this approval, and the balance is in progress [137].
Biomass energy	-Karnataka leads in the production of power through biomass, followed by Tamil Nadu and Gujarat [138]. -The main reason for high production in Karnataka is high due to raw materials available from the Western Ghats [139]. -About 60% of biomass resources in Tamil Nadu are available from woody biomass such as Prosopis Juliflora and Tapioca and the remaining through agricultural waste. Cogeneration of biogas is a most accomplished energy project as the sugar mills adhere to the latest techniques and encouragement by the Government [140]. -In Gujarat, this form of generation is gaining pace through the support of government and MNRE. They collaborate with farmers and buy the raw materials for generation and produce power and distribute it to the villages. About 70% of production is available from the waste of cattle [141].
Tidal energy	-The tidal energy inlets are currently identified along the west coast of India, including Gujarat and Karnataka [142], while scientists are currently identifying the economic possibility of harnessing tidal energy in Tamil

TABLE 2. *(Continued.)* **Detailed comparison of various sources of renewables for the studied three states.**

	Nadu. -Currently, 15 inlets in Gujarat and 16 inlets in Karnataka have the potential for tidal energy generation [74]. -Gujarat has two suitable locations with very high potential for tidal energy generation, namely Gulf of Kutch (1200 MW) with a range of 8m to 11m and Gulf of Cambay with an estimated potential of 7000 MW [143], while Karnataka still in the experimental stage, where private companies have submitted their prototype for the upcoming tidal plant of 10MW at Maravanthe beach [144].
Small hydel energy	-The installed capacity of Karnataka is 1254.73MW, which is 10 times larger than the production in Tamil Nadu (123.05MW) and Gujarat (61.30MW) [138]. -The numerous rivers in Uttara Kannada districts located in the mid-western part of Karnataka and bordering the Arabian Sea and suitable catchment areas and rainfall are the main reason for high production through these plants [74]. -Though Tamil Nadu stands best in production through other resources, its production through small hydro is low, but at present, we can see the growth in the establishment of projects through TANGEDCO near the running rivers. To meet the small-scale electrical requirements, the government encourages the NGOs and other associations to install watermills [145].

of the "private power policy," the private sectors started to participate effectively. It paved the way for the enhancement of wind power generation capacity in India [91].

The Acts, Policies, and regulations have been codified by the ministry to promote RE. India has both states as well as central level policies that support RE and aims in achieving a clean development mechanism [194]. Ten states have implemented the individual quotas for REs share of about 10 % out of 29, and low tariffs for electricity produced from renewable sources have been proposed [195]. Some of the significant policies and acts are discussed here.

A. RENEWABLE ENERGY CERTIFICATE (REC)

In 2010, the Central Electricity Regulatory Commission (CERC) had announced its regulations on the Renewable Energy Certificate mechanism. It is a green tradable certificate which was introduced to advocate renewable energy resources and marketing developments in electricity. Renewable energy certificate mechanism has facilitated the bound between the people to meet their Renewable Purchase Obligation (RPO) in those states that are deprived of renewable energy sources along with the open access consumers, captive power plants and distribution companies which have the option of purchasing the renewable energy certificate. RPO is a committee authorized by the State Electricity Regulatory Commission (SERC), to invest a meagre level of RE out of total consumption in the area of distribution licensee [196].

The Central Commission designates the registration of renewable energy certificate through a central level agency, and; renewable energy can be sold at a tariff which has been established by the electricity regulatory commission. The renewable energy certificate mechanism has contributed an opportunity for all types of renewable energy generators to accept the benefits by not worrying about the agreement related to power purchase for the trade of renewable power [197].

B. ELECTRICITY ACT (2003)

This act stands as a pillar for the upliftment of renewable energy in the country. This act was originated from three acts that were formed earlier, and these acts standardized electricity sectors-Indian Electricity Act (1910), the Electricity Act (1948) and the Electricity Regulatory Commission Act (1998) [198]. Few major regulations in the Electricity Act (2003) are: Section 3(1), Section 4, Section 61 (h), Section 86 (1) (e), Section 86 (2) (i) [199].

C. NATIONAL ELECTRICITY POLICY (2005)

The policy specifies that the contribution of electricity from renewable energy should be increased, and distribution companies adopt the process of competitive bidding for the purchase of power [200].

Some of the plans of the National Electricity Policy are:

- In the next five years, all households will have access to electricity.
- By the end of the year 2012, there will be no power demand and to increment the extra generating capacity, which can be done by increasing the output power of generators which are already connected through a power system.
- To supply a standard quality of power in a well-organized manner at a reasonable rate.
- By 2012, the per capita availability of electricity has to be expanded to over 1000 units.
- The electricity sector has to be supported financially and has to compete effectively to gain profit in the renewable energy sector.
- To know the requirement of the consumers and to ensure protection to them.

D. TARIFF POLICY (2006)

The central government revises this policy under section 3(3) of the Electricity Act 2003. It has been evolved as a result of discussions between the State Governments, the Central Electricity Authority (CEA), the Central Electricity Regulatory Commission, and various stakeholders. The main objective of this protocol is fixing a minimum percentage for purchasing energy, taking into consideration the presence of resources and its effects on retail tariffs and concerning the purchase by distribution companies. It also aims to provide

TABLE 3. Barriers in renewable energy.

Barrier	Description
High preliminary cost	-The capital cost of installing renewable energy plants is high when compared to non- renewable plants [143]. -It prohibits consumers from adopting them as they prefer to keep primary cost low instead of reducing the maintenance and operational costs [146]. -Lack of proper access to cheap capital parameters like inflation rate, interest rate during the installation of the RE source also contributes significantly to overall initial cost [147]. -Renewable purchase obligation's framework is not convincing, and the majority of the policies were applicable only to the existing technologies [148].
Economic and financial barriers	-The commercial banks are the one which helps in financing RE projects. Even though the banks give their support, the awareness was not spread, and lack of information about many solar power projects makes this help from banks impossible [132]. -The fund of renewable energy projects depends on issues like the size of the project, the developers, and the technology [149]. -When the debt or equity financiers demand is too high, the financing becomes costly. Mostly the banks are ready to fund small projects than the large projects [149]. -Some of the ways through which funding is provided are through foreign financing, syndicate loaning, and bridge loan [149].
Transmission and distribution losses	-An average of about 30% of losses has been observed during transmission, distribution, and usage of electricity [150]. -If RE generation takes place at a faraway place from the load centre, it will result in an acute increase of losses [150]. -These losses have to be monitored by the government by setting a separate department for the management of power distribution for more efficient management and integration of future RE generation centres to the grid [150]. -The increase in complexity of the power system increases the level of inverters also and leads to the high switching losses; this can be reduced by using bidirectional switches [151,152]
Technical barriers	-The main issue is the consumers are not aware of the new technologies due to lack of promotion. For example, from the customer's point of view, solar technologies are deceptive because they are abundantly available during the sunny period, and they are unaware that some technologies make them highly reliable when combined with hybrid photovoltaic systems [153]. -Mostly production of renewable energy depends upon the seasons, and hydropower depends upon the rainfall and availability of water. -The radiation that strikes on the globe depends on geographic locations, atmospheric conditions, and movement of earth. -In some places, the required data for starting a plant is not available, and so there is a need in the country to set up stations that helps in collecting the data regarding solar irradiance thereby fastening the advancements of solar power projects [110]. -The communication between the States regarding renewable energy sources should be keen to overcome the barriers. Therefore, information support is essential to achieve a perfect linkage for efficient RETs, and this will also lead to an increase the production [154]. -Another main problem is the lack of proper usage of the available resources, and there are no recognition and promotion of certain technologies like biomass integrated gasification combined cycle (BIGCC), co-firing, cellulosic ethanol, offshore wind energy generators [155].
Research and development	-Huge economic support is needed from the side of the government for research work, but this is currently unavailable. And further, the companies that absorb the market risk of introducing new technologies are unable to get the full benefits of their developments [156]. -Technically trained candidates with determined skills in management, and development; these people are not available due to insufficient training institutes. -There are inadequate guidance and technical backing for the engineers, which leads to the inefficient harnessing of renewable energy resources [157].
Land clearance problems	-The generation through hydro needs evacuation of people from the areas of the enormous potential of water for the construction of dams and this completely disturbs the habitats and animals present in that area. Difficulty in hiring experienced staff to install remote systems is another problem [158]. -The wind plants are laid on a farm, which is the bird's habitat and also leads to deforestation. So due to the blades of the turbine, most of the birds were killed, but some measures have been taken to protect birds by setting avian radars that detect birds in the area and will stop the turbine if there is a potential danger to birds from the turbines [159]. -A huge area is required for constructing a solar farm, and the major issue is to obtain the radiation data and identifying the hotspots [153]. -In the case of biomass, there is a risk with unproven fuel supply and conversion technologies, and the

TABLE 3. *(Continued.)* **Barriers in renewable energy.**

	generation cost is very high when compared to other generation methods. Another issue is the lack of support from the government to provide clearance to developers to construct plants.
Barriers faced in solar energy generation	-The generation through solar energy is the most prominent way but has few shortcomings [160]. The rise in PV panel temperature has adverse effects on the open-circuit voltage, short circuit current and accelerates the degradation process of the panel [161, 162]. Irradiance, air mass, wind speed, humidity, and module temperature have a significant influence on the PV module and decides the performance of the PV system [163]. -The maximum power point changes with variations in irradiance, panel temperature, and load. So, it shown monitored frequently [164]. These fluctuations can be monitored by an artificial neural network technique [165]. Energy losses can happen due to convection through the upper surface of the panel [166]. -Hence, to overthrow these drawbacks, the reflective coatings on the panel can be replaced by the anti-reflective chemicals. The problem is when we use the silicon cells; these have a very high reflective index which absorbs only a small amount of irradiance and converts it to energy while the other part is reflected back reducing the energy conversion. -So, the anti-reflective coatings like Aluminum oxide and Tantalum pentoxide [167] which will capture more energy and increase the output power and the efficiency can be increased through Phase Changing Materials (PCM) which acts as Thermal Conductivity Enhancers (TCE) [168-171]. -Flat plates, parabolic troughs, dish mirrors, heliostats are used as heating accumulating devices. These devices are costly and make it repulsive [172]. When the flat plate solar air heater was used, they have higher heat losses and lower heat transfer capability, which is not useful [173]. The angle at which the panel is placed (i.e. tilt angle) also influences the output power. The optimum tilt angle should be found to obtain a sound power output because the irradiance varies with season, time of day and geographic location and time to time the position of the panel should be change accordingly [174, 175] -The accumulation of dust on the panel will also lead to decreased efficiency. Frequent cleaning of the solar panel should be done [176].
Barriers in wind energy generation	-The majority of wind farms are installed in rural areas where the transmission grids are weak. So, this increases the cost of the total project, which includes the strengthening of grids along with the installation of the plant [177, 178]. -The shape, structure, and type of rotor blades used will influence power generation [179]. So, improvisations in the design of blades which will increase the strength and reliability of the system [180]. -Operation and maintenance for every individual component are costly [181]. -The selection of a wind turbine should be given special care because it is linked with the capacity factor. So, the wind turbine which is selected should be in such a way that it gives maximum capacity factor as well as the minimum cost of energy [182]. -The problem faced by the wind turbine is that it won't get the constant maximum power because of the variations in wind speed, which rotates the blades of the turbine. -To eliminate this Maximum Power Point Tracking (MPPT) controller is used in the rectifier side, which will use the concepts fuzzy logic control techniques. By tracking the reference speed of the generator and comparing it with the normal speed, the maximum power can be obtained. -And the use of a Permanent magnet synchronous generator (PMSG) will aid the system to operate with good stability and efficiency [183,184]. -The faults occur due to voltage sag. This can be made by improvising the mechanical structure of the wind turbine for the better production of energy [185]. -The massive wind energy systems use yaw control and pitch control for controlling the turbine generator, which is placed at the top of the tower. These control mechanisms were not possible in exploiting wind energy at the low speed [186] -Offshore wind energy plants are an emerging technology and transporting the generated electricity to the station placed on the shore through cables is a tedious process, and unique types of equipment to reduce the loss in transmission should be employed [187].
Absences of adequate energy management systems	-The monitoring and management of the renewable energy-based system is the major issue after implementation. -This can be set right by designing a system that can monitor the generation, the amount of power used, and faults in the system. The energy management through this system can be done through hybrid systems by implementing technologies like IoT, Python and other programming techniques [188]. -The utilization of resources is done, but the management of that resource is also an important thing. -Drones can be used efficiently in the solar energy field for surveillance, maintenance, and data logging [189].
Storage cells	-Superconducting magnet energy storage, flywheel energy storage, pumped storage batteries, regenerative fuel cell storage, and compressed air energy storage were used as storage devices [190]. Increase in the plant capacity will increase the capacity of the battery used for storage and which is not economical [191] -This can be overcome by using high exergy thermal energy storage and storing it thermally [192]

a better service to consumers through robust electricity infrastructure. It also ensures in creating adequate capacity, which includes assets in generation, transmission and distribution to produce reliability in electricity supply to the consumers [201].

E. NATIONAL ACTION PLAN OF CLIMATE CHANGE

This was formulated in the year 2008 to limit the emission of carbon concerning the protection and to accommodate the energy demand, and the government has launched a National Action Plan on Climate Change (NAPCC). The plan was started development through eight ''National Missions'' and to discuss the issues in climatic changes and about the steps to improve the utilization of Renewable Energy. The various ministries of the Government of India implement these missions, and the developments of every particular mission are constantly inspected by the Council on climate change which is governed by the Prime Minister of India. The main aim is to utilize the local government and public-private partnerships effectively and gratify global companies for research and development. Through the United Nations Framework Convention on Climate Change (UNFCCC), the transfer of technologies and funding is made easy [202]. Among the 8 national missions, the Jawaharlal Nehru National Solar Mission (JNNSM) is one of the major energy missions. It was launched in 2010 with an idea of increasing the generation through solar energy and by the end of 2022, it has targeted to set up 22000MW of power generation through off-grid and grid-connected plants [130], [203].

F. RURAL ELECTRIFICATION POLICY (2006)

The main objective is to ensure the accessibility of electricity to all the remote villages by the end of 2009, either through off-grid or grid-connected techniques. It cannot be entirely achieved through conventional methods, which arose an opportunity for solar, micro-hydro, wind and biomass technologies. The government has launched Rajiv Gandhi Grameen Vidyutikaran Yojana in the year April 2005; this is a scheme to electrify 125000 villages and also gives access to rural households in 5 years. By the end of December 2006, a total of 19.758 villages have been supplied with electricity [155].

IX. A PATHWAY FOR INDIA TO BECOME GLOBAL RENEWABLE LEADER

India is currently home to one of the most significant clean-energy expansions in the world. An increase in the Central Government and foreign investment drives the nation-wide green expansion. Still, the state governments can contribute a lot to fuel this transition. India is already among the top five global green energy producers in the world by the end of 2019 [204]. Newer technologies, steady influx of capital, falling prices of materials, and a highly conducive policy environment are among the most critical factors which determine the growth of new green energy projects. To emerge as a global leader in the renewable energy sector, India needs to aggressively rectify some prevalent issues dampening the growth of RE in the country. Moreover, it can adapt and implement successful strategies of other forerunners like China, Japan, Germany and the US in the RE sector.

Renewable based power plants need more substantial blocks of lands for construction and easing the land-acquisition norms will fasten current projects. About 31GW of renewable energy projects are in construction, and another 40 GW projects are out for tender in India. In 2005, China enforced the Renewable energy law (REL) to promote the development and utilization of RE and marked as the transition phase of RE development in the country. The law also fast-tracked the development projects and solved prominent barriers of RE generation in the country. Article 25 of REL promotes financial institutions to give preferential loans to renewable energy development projects [205]. Article 26 insists the central government provide tax benefits for these projects. The Ministry of Finance (MOF) issued a national taxation policy to favour RE projects. Moreover, Customs duty exemption is provided to import RE power generation equipment. Now whereas in India, still lack the interest of financial institutions to fund RE projects prevails. Also, the safeguard duty on imported solar panels, ambiguity over goods and services tax (GST) on solar equipment hinders the adoption rate of newer projects.

The government can rationalize the GST on solar and wind power equipment using a fixed standard national rate to improve fluidity in the sector. The Indian government can relax its taxation policies on RE technologies and provide more incentives for RE projects in the coming years. The new programs like Pradhan Mantri Kisan Urja Suraksha Utthan Mahabhiyan (PM-KUSUM), development of Ultra Mega Renewable Energy Power Parks (UMREPPs) which was implemented in 2019 contributed significantly to the growth of renewable energy installed capacity in the country [206]. The central government has been discussing the DISCOMs (Distribution Company) reform scheme for a long time, and it is yet to be implemented. The major highlight of the reform scheme is the privatization of debt-ridden DISCOMs to improve their performance.

Moreover, modernization of current transmission networks and further expansion of it may fuel the large-scale connection needs of RE production hubs. There is a recent slowdown in addition to newer transmission capacity in the country with about only 10625 ckt km (Circuit kilometres) to be added in the current FY 2019/2020 whereas in previous FY 2018/19 and FY 2017/18 in was 25000 ckt km [206]. The lack of adequate transmission networks in key production hubs has kept the project developers from bidding for these RE projects. The Power Grid Corporation of India Limited (PGCIL) has recently shared proposals to set up large scale transmission networks in states of Maharashtra, Gujarat, and Rajasthan to support a combined 25 GW of renewable energy projects in these states [207].

The concentrating solar power, micro fuel cell and floating wind turbine technologies are the areas of prime focus to improve the efficiency of renewable energy generation. India should also incorporate the latest technologies through government-private partnerships to improve the efficiency of current installed capacity. More attention is needed on energy storage development projects and also energy transport on a more economical scale. Improved energy conservation techniques in heating, ventilation, and air conditioning (HVAC) needs to be taken care. These are the significant areas of concern to be focused on to improve the RE growth rate and efficiency in the country and to become one of the largest green energy producers in the world. Some of the significant technological developments that can be made to make India a global leader-

Solar:

- ✓ For achieving the target of 2022, the country should face challenges like poor quality of solar modules, financial sickness of state distribution companies and others. India highly focuses on generation through solar photovoltaic (PV) cells; efficiency is about 29 % (for single-junction silicon solar cells), and this efficiency reduces due to heating losses, dust, and weather. Moreover, the majority of plants use thin-film solar cells. They have a lower efficiency of about 7 to 13 % only, which is much lower than crystalline silicon solar cells. And using thin-film will also reduce its output as the years' pass, and it requires a massive area for setting up the plant. But the same plant with the same generation can be set by crystalline silicon solar cells in a less area and with higher efficiency. So, by replacing the thin film with crystalline silicon cells can help India to achieve its target [208].
- ✓ The panel efficiency reduces as the PV module temperature increases and this reduces the overall output [209]. The cooling techniques like air cooling, water-based cooling, liquid immersion cooling, thermoelectric cooling, active water cooling, phase change materials (PCM) can be adopted to increase efficiency [210].
- ✓ Efficiency is also reduced due to reflective and thermal losses which can be overcome by using the anti-reflective coating technology [211].
- ✓ Even the dust accumulated on panels will cause a drastic decrease in its efficiency. For overcoming the dust; cleaning technologies should be encouraged. Techniques like electrostatic method (standing-wave electric curtain, Travelling- wave electric curtain), mechanical methods (brushing, blowing, ultrasonic vibration methods) and coating methods (super hydrophilic or superhydrophobic coatings) [212], [213]

Wind:

- ✓ Wind Power is the leading renewable energy generation in the country and to achieve future renewable energy targets, only adding new capacities is insufficient.
- ✓ Existing wind energy plants need to be modernized and periodically upgraded to improve plant efficiency and minimize operational costs.
- ✓ Modern tools like the Simulator for Wind Farm Applications (SOWFA) can help in improving the efficiency of the plant. SOWFA is a set of CFD (computational fluid dynamics) solvers, turbine models, boundary conditions based on the Open FOAM CFD toolbox. This tool allows users to simulate wind turbines and plant operation and performance under the full range of atmospheric conditions and in terrain.
- ✓ The usage of SOWFA is highly helpful in coordinating turbine controls for curtailing wake effects. The wind power plant output could be increased by 4%-5% [214].
- ✓ Offshore wind energy research should be encouraged in the country [215]. Advanced control methods should be used to produce innovative controls for offshore floating wind turbines. Moreover, the stress on structural load should be reduced, and platform motion must be limited to increase reliability and maximize energy production.
- ✓ Moreover, offshore technology development should aim to lower the operational cost and should be able to produce utility-scale grid-connected energy.
- ✓ Maintenance of wind turbines and related components is also a concern as to cost increases with its age. The NREL(National Renewable Energy Laboratory - United States) has developed a new variant of Gearbox which uses journal bearing instead of roller bearing(To improve lifespan and avoid frequent failures and to make it lighter) and flex pins to improve load sharing between various gears in a sun/planet configuration [216].
- ✓ Drive trains used in the turbine are highly advanced nowadays with the development of the WindPact drive train project. The single-stage planetary drive operates at a gearbox ratio of 9.16:1 and a significantly lesser diameter of 2 meters (for a 1.5 MW generator). Many R&D resources and several years are needed to develop into a reliable production project yet India can modernize its current fleet of components used to improve overall performance [217].
- ✓ Smarter turbines are next-gen technologies where smart rotors with a very active control surface which employs built-in blade intelligence for significantly decreasing turbine costs and also to reduce rotor blade loads [216]. Embedded turbine sensors are programmed to gather the data, and detailed analysis is done in real-time on factors like temperature or vibrations and transmits the necessary data to adjust which help in improving efficiency.
- ✓ Other non-technical concerns also need to be addressed for further developments. Getting land clearance is very difficult, especially in Western India. For many states, still actual wind potential is unknown, and it should be identified for long term planning [218].
- ✓ The output power maximization can be obtained through fuzzy controller technologies [219]. There are the chances of fault occurrence in the grid side and to

avoid disruptions due to these faults PI controller can be used to bring back the grid side converter to its normal state [220].

The technologies discussed above are among a few ways which can help India to modernize the current fleet of RE generation and also exponentially increase the current installed capacity of green energy and reach its target efficiently on time. The states with the lower generation capacity can adopt these technologies to improve their production. To increase production, only adopting newer technologies is not sufficient. The non-technical aspects discussed above also play a considerable role in determining the RE growth in the country. Care should be taken to improve interest among investors to aid new projects. The government needs to frame and modify its policies dynamically to aid faster adoption of new-age technologies. The outlaid pathway presents one of many possible ways for India to become a global leader in renewable energy production.

X. FUTURE PROSPECTS OF RENEWABLE ENERGY

Renewable energy in India has been developing day by day and increasing its penetration into the energy mix. Some of the future initiatives or proposed developments of the country to accomplish 175 GW of installed capacity from RE resources by 2022 has been highlighted in this section. It will encompass solar energy of 100 GW, wind energy of 60 GW, small hydropower of 9 GW, biomass-based projects about 5 GW, and 1 GW using through other RE resources [221]. The implementation of RETs would reduce the cost, and these resources lead India towards a great future. For achieving this progress in renewable energy generation, all government agencies as well as non- governmental organizations, R&D institutions are needed along with budding young entrepreneurs. These renewables will help in the overall development of the country's economy, and about Rs.3000000 million will be invested in this field for the next 25 years. By 2022, renewable energy's total share is estimated to be 15.9%.

An innovative scheme called as tail-end grid is being developed by the country and this has been emphasized on large plants. The biomass plants have to face difficulties in collecting and transporting fuels, which lead it to stick with smaller plants. By considering transmission losses into account, the future is favourable to smaller plants. For example, the plants of 100 KW to 2MW capacity would lessen the losses by 5-7% when compared with plants with a vast capacity of 50-100MW, and parallelly they develop the voltage and frequency issues. By modernization of the existing power cogeneration plants, the potential of production through bagasse cogeneration is expanded. By 2022, the estimated potential through SHP is about 15000 MW, and 5718 sites are identified. About 285 projects of about 940 MW are in the preliminary stages. It aims in an addition of 300 MW per year and in which 70% is coming through private sectors [222]. In case of solar energy, it is building its generation capacity day by day, and a target of 2022 is to install 20 million square meter solar thermal collector area and off-grid capacity including 20 million solar lighting systems which is of capacity 2000MW, and it is the part of Jawaharlal Nehru National Solar Mission [223]. The wind-solar hybrid policy was finalized by MNRE in the year 2016, and a keen goal has been set to attain about 10 GW capacity hybrid plants by the end of 2022 [224].

The state of Tamil Nadu would have renowned RE with equipped capacity by 2022. For meet the energy load demand reliably, the state must start and move on to some steam turbine units frequently at the thermal minimal. In 2022, the total load is predicted to change symbolically between 1.3 GW to 14.6GW, which indicates that this increase in load can be met through renewable energy resources [225]. The Tamil Nadu government is currently focusing on wind and solar energy generation projects on a large scale to use 20 - 25 % of RE by 2020. Through analysis, it is noted that the Thirupullani surroundings of Ramanathapuram have the most promising area to start hybrid plants. Just like rainwater harvesting, which was successfully implemented in Tamil Nadu in the same way, the government started to provide importance to RE generation in all places through fresh protocols and motivation. The private sectors and consumers started developments in rural areas by constructing mini and micro-hydro projects. And to supply a sum of 226 MW of solar power through 90 stakeholders has been started and the initiative has been made to minimize transmission and distribution losses by setting solar plants in their buildings [93].

There is a keen interest in financing the generation through tides from the international market, especially in India, due to its good coastline and as a result, the British Tidal association initiated 250 MW tidal plants in the area of Gujarat near Gulf of Kutch. The generated power can be utilized in domestic and business as well as industrial applications [80]. The future of RE is in offshore wind power plant, tidal plants, and geothermal plants. The Indian government has planned to set up the research and development centres and support them financially for their research [226]. The world's most abundant mangroves are present near the seashore of Kutch and Cambay as per the present renewable energy report. So, the Indian government had planned to develop a tidal power plant near the Gulf of Kutch and Sundarbans delta of West Bengal. In Gujarat, a 50 MW plant is productively dispatched, and it is extended to 250 MW. But as per the evaluation of the Government of India, the potential capacity of the Gulf of Kutch is 1100 MW, and the Gulf of Cambay is 7500 MW. A 10 MW tidal energy plant was affirmed by the Gujarat Government which was projected by Urja Global Limited in connection with US-based organization Ocean Energy Industries, but this has not yet started because of lack of appropriate arrangements for the improvement of this tidal energy division [80].

The Indian Government will establish offshore wind capacity of about 5MW at the end of 2022. The government of Gujarat has planned to install 1 GW capacity plant at the offshore. There is a need for further improvements in R&D

and to support the ideas and plans of international investors in this field, and accurate and constant measurements in ministries with exceptional policies can be started [60].

The solar energy has put some specific targets to meet the future energy demands by starting the yearly target of the rooftop and ground-mounted solar systems. The rooftop solar system has a target of 40 MW out of 100 MW total solar energy targets. After the success of "Charanka Solar Park" in Gujarat, the government has planned to start the solar parks and mega solar power projects of 500 MW and more [227].

The solar policy aspires a target of 1000 MW of solar energy generation, and about Rs.130 billion was announced in 2009, which promise to generate 20 GW of solar energy by 2020 in the state [228]. In India, the geothermal energy plants are only present in Gujarat, and the state and central government did not yet develop this, and it needs a high investment.

The renewable energy transition from conventional sources is slowly gaining pace, not only in India but also around the world. The latest technologies and upcoming new inventions and ideas contribute a lot in improving the efficiency and implementation of renewable energy everywhere. Thus, it is believed that by adopting various measures and switch over to renewable energy, we can make this planet a better home for future generations

XI. CONCLUSION

Global warming, energy costs, and energy crisis have encouraged interest worldwide in the past decades towards an alternative and cleaner method for power production. Accordingly, the United Nations laid down SDGs for attaining a sustainable, cleaner, environment-friendly energy production in the future. Global countries like China, the USA, Germany, and Sweden are leading the pack by rapidly increasing it's renewable energy capacity and framing policies and fixing deadlines to achieve its target. India has targeted to accomplish 175 GW of energy from renewable energy sources by 2022, to meet the energy demand of 1.36 Billion people and counting. While every state is framing its specific policies and frameworks to achieve their target, Karnataka, Gujarat and Tamil Nadu are the front runners in quicker adoption of renewable energy generation in India and these three states alone account for 44% of total installed capacity of RE production as of May 2019. Each state has framed its energy policies following its physical and geological landscapes for promoting suitable renewable energy.

This study scrutinized the global policies to promote renewable energy in particular, the policies of leading renewable energy generating countries from a different continent.

This study not only addressed the prospects and growth of renewable energy, existing policies in India to promote its integration into the energy mix but also addressed the significant barriers that hinder the growth of renewable energy in the nation.

This study has done an in-depth analysis of the renewable energy scenario of three states, which gives an insight into their potential, installed capacity and policies.

The government will use this review study, industrialists, local and global investors, and stakeholders, policymakers and researchers as a promising guideline for their planning and work regarding renewable projects in India as well as around the world.

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